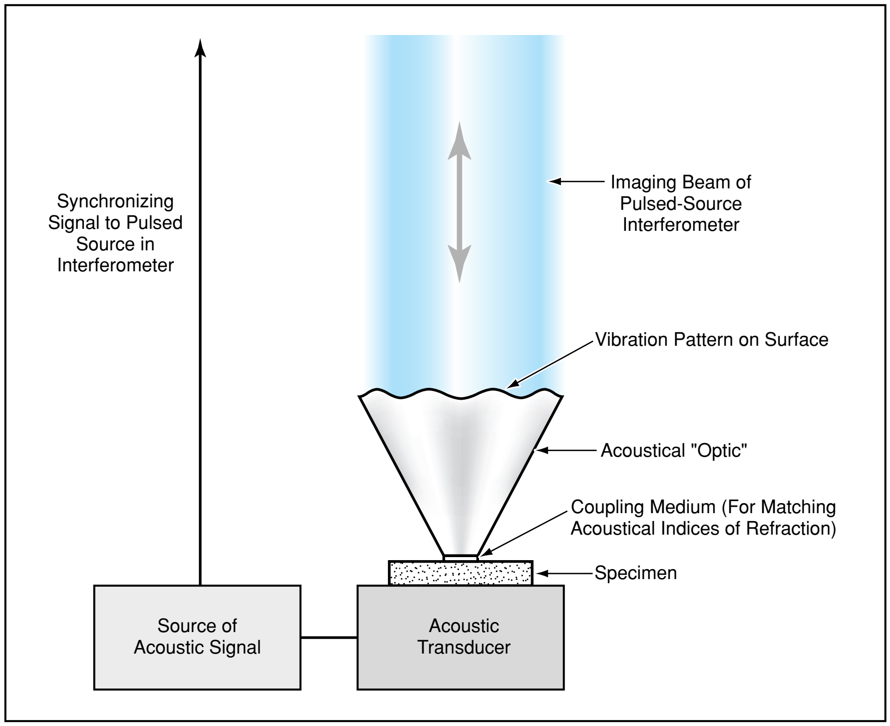
Pulsed-Source Interferometry in Acoustic Imaging

Buried features as small as 30 nm could be resolved.

NASA's Jet Propulsion Laboratory, Pasadena, California

A combination of pulsed-source interferometry and acoustic diffraction has been proposed for use in imaging subsurface microscopic defects and other features in such diverse objects as integrated-circuit chips, specimens of materials, and mechanical parts. A specimen to be inspected by this technique would be mounted with its bottom side in contact with an acoustic transducer driven by a continuous-wave acoustic signal at a suitable frequency, which could be as low as a megahertz or as high as a few hundred gigahertz (see figure). The top side of the specimen would be coupled to an object that would have a flat (when not vibrating) top surface and that would serve as the acoustical analog of an optical medium (in effect, an acoustical "optic").

Microfeatures within the specimen would diffract the acoustic wave. The diffracted wave would propagate through the acoustical "optic," forming a vibration pattern on the top surface. The vibration pattern would be measured twice by use of a pulsed-source optical interferometer; the first measurement would be taken in phase, the second 90° out of phase with the acoustic signal at its source. The amplitude and phase of the vibration pattern, and thus of the acoustic field, would be computed from the two measurements. Then by use of a diffraction formula, the acoustic pattern would be computationally propagated back into the specimen to obtain an acoustic image of the internal microfeatures.



A **Pulsed-Source Interferometer** would be used to measure the phase and amplitude of a vibration pattern related to acoustic diffraction by microfeatures in the specimen. The pattern would then be used to compute an acoustic image of the microfeatures.

The pulsed-source interferometer has already been demonstrated, in a different application, to afford an amplitude resolution as small as 1 nm. With refinements in design and operation, it should be possible to resolve amplitudes an order of magnitude smaller. If, in addition, the acoustic frequency were at least 30 GHz, then it should be possible to image features as small as 30 nm. The ability to image at such high resolution would be a significant contribution to the art of nondestructive microscopy. Of course, lower acoustic frequencies could be used to image larger features in applications in which the highest resolution is not needed.

This work was done by Kirill Shcheglov, Roman Gutierrez, and Tony K. Tang of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*
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Thermo-Electron Ballistic Coolers or Heaters

These devices may surpass currently available thermoelectric devices.

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Electronic heat-transfer devices of a proposed type would exploit some of the quantum-wire-like, pseudo-superconducting properties of single-wall carbon nanotubes or, optionally, room-temperature-superconducting polymers (RTSPs). The devices are denoted thermo-electron ballistic (TEB) coolers or heaters because one of the properties that they exploit is the totally or nearly ballistic (dissipation or scattering free) transport of electrons. This property is observed in RTSPs and carbon nanotubes that are free of material and geometric defects, except under conditions in which oscillatory electron motions become coupled with vibrations of the nanotubes. Another relevant property is the high number density of electrons passing through carbon nanotubes — sufficient to sustain electron current densities as large as 100 MA/cm^2. The combination of ballistic motion and large current density should make it possible for TEB devices to operate at low applied potentials while pumping heat at rates several orders of magnitude greater than those of thermoelectric devices. It may also enable them to operate with efficiency close to the Carnot limit. In addition, the proposed TEB devices are expected to operate over a wider temperature range.

A typical TEB device (see figure) would include an electrically and thermally conductive plate, denoted the hot plate, on the side from which heat is to be transferred; *N* layers (*N* = 3 in the figure) of bundled and aligned carbon nanotubes interspersed